Journal of Fiber Bioengineering and Informatics 11:3 (2018) 151–161
doi:10.3993/jfbim00283

Enhanced Photocatalytic Degradation of Acid Orange 7 by AgBr/$BiVO_4$ under Visible Light

Jian-Hua Ran [a,b,*], Xing Fei [a], Lv Ni [a], Felix Telegin [a,*]

[a] *Hubei Key Laboratory of Biomass Fibers and Eco-dyeing & Finishing, Wuhan Textile University, Wuhan 430073, China*

[b] *Ivanovo State University of Chemistry and Technology, Sheremetevsky Ave 7, Ivanovo 153000, Russia*

Abstract

Recently, the use of co-catalysts has been an important alternative method to improve the visible light photocatalytic activity of pure semiconductor materials. A novel photocatalyst AgBr/$BiVO_4$ was prepared by hydrothermal synthesis and chemical deposition method. The degradation of acid orange 7 was enhanced by AgBr/$BiVO_4$ than pure $BiVO_4$, which was eliminated 92.96% within 80 min under visible light irradiation. It was found that the doping of AgBr could greatly improve the photocatalytic activity of $BiVO_4$ by reducing the recombination of electrons and holes. Prepared photocatalysts were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), UV-vis diffuse reflectance spectra techniques (UV-vis) and X-ray photoelectron spectroscopy (XPS).

Keywords: AgBr/$BiVO_4$; Hydrothermal; Chemical Deposition; Photocatalytic; Visible Light

1 Introduction

With the development of economy and society, environmental pollution is increasing seriously, especially in water pollution. Dye pollution is an important source of water pollution which is difficult to eliminate with conventional water treatment technologies [1]. Recently, photocatalytic technology is a very effective method for degrading organic water pollutants. It not only degrades different dyes, but also causes their complete mineralization to carbon dioxide (CO_2), water (H_2O) and mineral acids [2]. According to common understanding of the photocatalytic reactions based on outstanding discovery of semiconductors, they are initiated by the absorption of a photon with appropriate energy that is equal to or higher than the band gap energy of the photocatalyst. The absorbed photon creates a charge separation as the electron (e^-) is elevated from the valence band (VB) of a semiconductor to the conduction band (CB), creating a hole (h^+) in the VB, initiating several reducing or oxidizing processes. Monoclinic bismuth vanadate ($BiVO_4$) has attracted much attention due to its relatively narrow band gap (E_g = 2.4 eV), high chemical stability and non-toxic [3-5]. However, photocatalytic activity of pure $BiVO_4$ is relatively low due to its

*Corresponding author.
Email addresses: jhran@wtu.edu.cn (Jian-Hua Ran), felix.telegin@gmail.com (Felix Telegin).

Sep. 2018

poor adsorptive performance and difficult migration of electron-hole pairs [6]. Currently, there are two major methods to improve its photocatalytic activity. The first method is to increase the specific surface area by producing $BiVO_4$ with different morphologies and smaller size, such as spheres, sheets and tubes [7-9]. On the other hand, researchers found that some noble metals (Ag, Pt, Pd) loaded on the $BiVO_4$ surface or coupling with other semiconductors could efficiently improve its photocatalytic activity, such as $CuO/BiVO_4$ [10, 11], $Co/BiVO_4$ [12], $TiO_2/BiVO_4$ [13], $BiVO_4/ZnO$ [14] and $Cu_2O/BiVO_4$ [15].

In recent years, the use of co-catalysts (metals or metal oxides) [16-18] has been an important alternative method to improve the visible-light photocatalytic activity of pure semiconductor materials. In comparison with conventional semiconductor photocatalysts, the coupling semiconductor has been proved to be an effective way to develop high performance photocatalysts for the decomposition of various organic contaminants, attributing to improve charge separation efficiency and multifunctional spectral response. Until now, various coupled photocatalysts based on constituted semiconductors with matched band potentials, such as TiO_2-SnO_2 [19, 20] and $CuBi_2O_4/BiVO_4$ [21], have been designed and investigated. The silver/silver halides (denoted as Ag/AgX, X = Cl, Br) is one type of plasmonic photocatalysts which can work under visible light for pollutant degradation, water disinfection, and carbon dioxide reduction [22, 23]. For example, a plasmonic Ag-AgBr/TiO_2 [24] composite photocatalysts exhibited obviously enhanced photocatalytic activity for the degradation of MB dye in the visible light. AgI/TiO_2 [25, 26], Ag/$BiVO_4$ [27-29], AgBr/BiOBr [30] and other composite photocatalysts are synthesized, these photocatalysts containing silver halide maintained a good stability and photocatalytic ability. In Chen's paper [31], AgI/$BiVO_4$ was synthesized by an in situ precipitation, which exhibited higher degradation efficiency (94.91%) within 1 h of visible light irradiation.

In this paper, AgBr modified $BiVO_4$ composite photocatalysts were prepared by hydrothermal synthesis method and chemical deposition method. Prepared photocatalysts were characterized by X-ray diffraction (XRD), scanning electron microscopy (SEM), UV-vis diffuse reflectance spectra techniques (UV-vis) and X-ray photoelectron spectroscopy (XPS). The photocatalytic performance of AgBr/$BiVO_4$ was evaluated by the photodegradation of Acid Orange 7 under visible light irradiation.

2 Experimental

2.1 Materials

All of the reagents are analytical grade and used without further purification. Solutions were freshly prepared with distilled water. Bismuth nitrate pentahydrate ($Bi(NO_3)_3{\cdot}5H_2O$), ammonium vanadate (NH_4VO_3), nitric acid (HNO_3), ammonia ($NH_3{\cdot}H_2O$), sodium hydroxide (NaOH), silver nitrate($AgNO_3$), potassium bromide (KBr) and ethanol (C_2H_5OH) were purchased from standard sources (China National Medicines Corporation Ltd.)

2.2 Preparation of Composite Photocatalyst

$BiVO_4$ photocatalysts were synthesized through a hydrothermal process. 5 mmol $Bi(NO_3)_3{\cdot}5H_2O$ was initially dissolved in 40 mL of nitric acid, followed by addition of 5 mmol NH_4VO_3 and